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(54) A positioning device comprising pre-stressed contactless bearings.

(57) A Positioning device having a plate-shaped carrier (5) which is slidably supported on a table (1) and is displaceable in a horizontal plane and on which a pressure force and a tensile force, respectively, are exerted by means of at least two translatory drives (11, 13). The translatory drives (11, 13) are coupled to the carrier (5) by means of horizontallyoperating static thrust and tensile bearings, respectively (33 to 41, 49) which via a viscous medium transmit pressure and tensile forces, respectively between the carrier (5) and the translator drives (11, 13) in a contactless manner. The contactless bearings (33 to 41, 49) are pre-stressed with a force which is larger than the maximum tensile force occurring between the drives (11, 13) and the carrier (5). Thus a substantially frictionless coupling is obtained between the drives (11, 13) and the carrier (5). This coupling acts at the same time as a guide for the carrier (5).

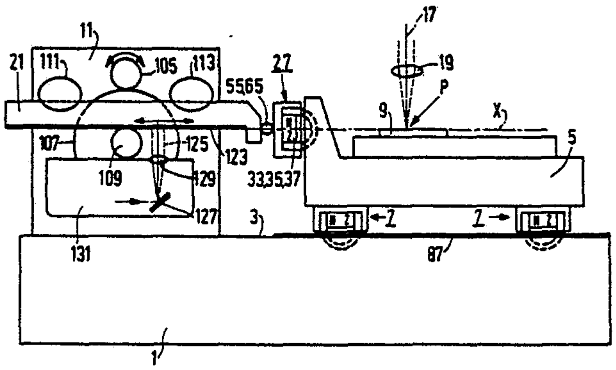

FIG.2

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"A positioning device comprising pre-stressed contactless bearings."

The invention relates to a positioning device comprising a horizontal plate-shaped carrier which is slidably supported on a flat table and is displaceable in two orthogonal coordinate directions, which device is provided with a first translatory drive coupled to the carrier for exerting a pressure force on the carrier in a first coordinate direction and with a second translatory drive coupled to the carrier for exerting a pressure force on the carrier in a second coordinate direction at right angles to the first coordinate direction, the forces exerted on the carrier by the first and the second drive acting in one horizontal plane.

In the known positioning device of the kind mentioned in the opening paragraph (US-PS No. 3466514), the translatory drives coupled to the carrier are constituted by a screw spindle, opposite which a spring-loaded plunger is arranged. The directions of movement of the screw spindle and the plunger coincide with each other. A pressure contact with a comparatively high degree of frcition exists between the end of the screw spindle and the end of a plunger rod connected to the plunger on the one hand and the carrier on the other hand. This friction is undesirable due to the hysteresis attendant thereon, especially if the carrier has to perform very small displacements in the micron and submicron range.

The invention has for its object to provide a positioning device in which the above disadvantages are avoided.

For this purpose the invention is characterized in that the first drive is coupled to the carrier in a contactless manner by means of a first horizontally operating static thrust and tensile bearing, respectively, via a viscous medium, while the second drive is coupled to the carrier in a contactless manner by means of a second horizontally operating thrust and tensile bearing, respectively, via a viscous medium, bot the first and the second thrust and tensile bearings, respectively, being pre-stressed in the first and second coordinate direction, respectively, with a force which is larger than the maximum tensile force occurring between the first and the second drive on the one hand and the carrier on the other hand.

By the use of pre-stressed contactless bearings as coupling means between the drives and the carrier, substantially the whole amount of friction between the drives and the carrier is eliminated (only a very small viscous friction remains present) so that hysteresis problems are avoided. The pre-stressed state of the contactless bearings renders it possible to exert with the drives a tensile force on the carrier so that in fact a thrust-tensile bearing is formed. The bearings have a dual function because they serve as guide and as coupling.

It should be noted that British Patent Application 2067932 discloses a positioning device comprising a vertically operating aerostatic thrust bearing which can be pre-stressed by a spring. However, this thrust bearing serves for horizontally guiding the carrier on a table. The coupling of the spindle drives to the carrier is effected by means of pivots.

A particular embodiment of the positioning device according to the invention, in which the carrier can perform besides the translations in the two coordinate directions also a rotation about a vertical axis, is further characterized in that the device is provided with a third translatory drive coupled to the carrier for exerting a pressure force and a tensile force, respectively, on the carrier in a direction parallel to the second coordinate direction, the first, the second and the third drive each being pivotable about a vertical axis with respect to the carrier.

A further embodiment of the positioning device, in which the pre-stress of the three bearings is obtained in a constructionally simple manner, is characterized in that the first, the second and the third bearing are pre-stressed by means of a permanent magnet arranged therein.

A preferred embodiment of the positioning device, in which load variations lead to a comparatively small variation of the bearing capacity, is further characterized in that a part of the magnetic circuit corresponding to the permanent magnet is in the state of magnetic saturation.

A still further embodiment of the positioning device, which is suitable for use in conditioned rooms, is characterized in that the viscous medium is air.

A further embodiment of the positioning device having a comparatively simple arrangement of the permanent magnets is characterized in that the second and the third bearing are pre-stressed by means of a number of permanent magnets common to both bearings, which are arranged in the carrier.

A still further embodiment of the positioning device, in which the carrier has a comparatively high degree of rigidity against rotation about a vertical axis, is further characterized in that the second and the third bearing are coupled to each other by means of a beam-shaped guide, which is pivotable with respect to the second and the third drive about a vertical axis, while the first drive is pivotable about a vertical axis with respect to the carrier.

The invention will be described more fully with reference to the drawings, in which:

Fig. 1 is a diagrammatic perspective view of a first embodiment of the positioning device,

Fig. 2 is a diagrammatic side elevation of the positioning device shown in Fig. 1,

Fig. 3 is a diagrammatic plan view, drawn to a reduced scale, of the positioning device shown in Fig. 1 after a rotation of the carrier 5 about a Z-axis,

Fig. 4 is a diagrammatic plan view of a second embodiment of the positioning device,

Fig. 5 is a diagrammatic plan view of a third embodiment of the positioning device,

Fig. 6 is a longitudinal sectional view of part of the positioning device shown in Fig. 1,

Fig. 7 is a plan view of part of the positioning device shown in Fig. 6 from a first side,

Fig. 8 is a plan view of part of the positioning device shown in Fig. 6 from the second side,

Fig. 9 is a diagrammatic perspective view of a thrust and tensile bearing, respectively, for all coordinate directions of the positioning device,

Fig. 10 is a graph illustrating the principle of the operation of a thrust and tensile bearing respectively,

Fig. 11 is a perspective bottom view of the carrier drawn to a scale which is smaller than the scale of Figures 6, 7 and 8,

Fig. 12 is a longitudinal sectional view of a translatory drive for the positioning device.

The first embodiment of a positioning device shown in Fig. 1 comprises a fixedly arranged flat table 1 in the form of a rectangular planoparallel plate, the sides of which are located in horizontal planes. A rectangular plate-shaped carrier 5 is slidably supported on the upper surface 3 of the table 1 by four (multiple) vertically operating aerostatic thrust bearings 7, which are arranged near the corners of the carrier 5. On the carrier 5 is disposed an object 9 to be positioned, which object is plate-shaped and which can be secured on the carrier by, for example, vacuum suction means. The object 9 may be, for example, a wafer of semiconductor material used in semiconductor technology. The carrier 5 can be displaced in a first coordinate direction X by means of a translatory drive 11, which is of the so-called linear type, while it can be displaced in a second coordinate direction Y by means of a similar translatory drive 13. A third translatory drive 15 of a similar kind to the drives 11 and 13 serves at the same time to rotate the carrier 5 through an angle ϕ_Z about a Z-axis, which is illustrated in Fig. 1 by a coordinate system. The X-Y plane is a horizontal plane, in which the upper surface of the object 9 has to be displaced. The translations in the X-and the Y-direction and the rotation about the Z-axis may be effected arbitrarily separately or simultaneously by means of, for example, a computer control of the drives 11, 13 and 15. These drives will be explained more fully with reference to Fig. 12. In the present case, a working point P on the upper surface of the object 9 should coincide with a vertical optical axis 17 of an optical device 19 (see Fig. 2) for exposing a photo-sensitive layer on the wafer 9. The translations in the X-and Y-directions and the rotation ϕ_Z about a Z-axis required to this end may be determined, for example, by a method as described in the aformentioned US-PS No. 3466514.

The drives 11, 13 and 15 have straight rods 21, 23 and 25, which can perform translations in the X-direction, the Y-direction and the Y' direction, respectively, the latter direction being parallel to the Y-direction and lying in the X-Y plane. The rotation ϕ_Z can be obtained by means of the drive 15 by displacing the rods 23 and 25 in a given period of time over different distances. The rods 21, 23 and 25 have supporting feet 27, 29 and 31, respectively, secured to them by means of pivots to be described more fully hereinafter with reference to Fig. 6. The supporting foot 27 accommodates a first part of a thrust and tensile bearing, respectively, for exerting a pressure force and a tensilt force, respectively, in the X-direction. The supporting feet 29 and 31 are also each provided with a first part of a thrust and tensile bearing, respectively, for exerting a pressure force and a tensile force, respectively, in the Y-direction and the Y' direction, respectively. The thrust and tensile bearings, respectively, corresponding to the supporting feet 27, 29 and 31 are identical and will be described hereinafter with reference to Figures 6, 7, 8 and 10. In the supporting foot 27 (and also in each of the supporting feet 29 and 31 there are arranged three plate-shaped permanent magnets 33, 35 and 37 of rectangular shape, which are separated from each other by two rectangular plate-shaped magnet yokes 39 and 41 of good magnetically conductive material. The assembly of permanent magnets and magnet yokes is situated in a box-shaped holder 43 of poor magnetically conductive material, such as, for example, aluminium, and is separated therefrom by two further rectangular plate-shaped magnet yokes 45 and 47 of good magnetically conductive material. In the present case, the permanent magnets are samarium-cobalt magnets, while all the magnet yokes are made of mild steel. Opposite the permanent magnets 33, 35 and 37 there is arranged in the carrier 5 a plate 49 of good magnetically conductive material, such as, for example, chromium-steel. The plate 49 forms the second part of the thrust and tensile bearing, respectively. the magnets 33, 35 and 37 are magnetized in the Z-direction. The holder 43 has secured to it a rectangular block 51 of aluminium. On the block 51 is mounted a circular plate 53, which is manufactured together with a comparatively short wire 55 of round cross-section and a cylindrical block 57 from one piece of steel. The rod 21 is provided with a flange 59 in which is accommodated a screw 61 which is screwed into the block 57. The flange 59 has secured to it a cylindrical sleeve 63 formed with an annular diaphragm 65 which is provided with a thickened circular edge 67, which is screwed to the plate 53. The sleeve 63, the diaphragm 65 and the edge 67 are manufactured from one piece of steel. The diaphragm 65 forms togehter with the wire 55 a pivot, by means of which the supporting foot 27 can tilt with respect to the flange 59 in the vertical plane (the plane of the drawing in Fig. 6) and in the horizontal plane (at right angles to the plane of the drawing in Fig. 6). The coupling thus obtained between the supporting foot 27 and the flange 59 is rigid against torsion, which means that a large resistance is offered to rotation of the supporting foot 27 about the X-axis. The block 51 is provided with a duct 69 connected to a source of compressed air (not shown) for the supply of air to the air gap between the supporting foot 27 and the plate 49 and the carrier 5, respectively. For this purpose, the duct 69 is connected to two lateral ducts 71 and 73, which are located on either side of the assembly of magnets (Fig. 9). Fig. 2 shows diagrammatically the supporting foot 27 and the coupling of the supporting foot 27 to the rod 21 (only one magnet is shown). The regions of the air bearing and the magnetic pre-stress are consequently separated from each other. The supporting feet 27, 29 and 31 constitute together with the corresponding plates 49 and the associated air gaps a thrust and tensile bearing respectively, which can transmit both pressure and tensile forces from the rods 21, 23 and 25 to the carrier 5. Normally, a viscous contactless bearing can transmit only pressure forces. In the case of the present static air bearing, however, tensile forces also can be transmitted. This is due to the fact that the bearing is magnetically pre-stressed by means of the permanent magnets 33, 35 and 37. The magnetic pre-tension must be larger than the maximum tensile force exerted by the rod 21 on the carrier 5. The tensile force in the rod 21 is twice the tensile force in each of the rods 23 and 25. The maximum tensile force is mainly determined by the required acceleration and deceleration forces, respectively, for the translatory and rotary movement, respectively, of the carrier 5. In generaly, a smallest possible mass of the carrier 5 and the object 9 present thereon will be aimed at. In order to obtain a bearing having optimum properties, more particularly in order to obtain a bearing having an optimum rigidity, it is preferable to choose the magnetic pre-stress so that with a changing load of the bearing a smallest possible variation of the size of the air gap occurs. The optimization of the bearing will be described hereinafter with reference to Fig. 10, in which the size H_a of the air gap is plotted on the abscissa, while the bearing capacity W and the magnetic attraction force F of the bearing are plotted on the ordinate.

In Fig. 10, the curve I represents the bearing capacity of the bearing. It is assumed that the working point R is located in the middle of a region of the curve I, which is characterized by a substantially constant rigidity

$$\frac{dW}{dH_a}$$

of reasonable value and which lies between the bearing capacity values W_1 and W_2. The bearing capacity associated with the working point R is W_R. Air bearings having such a characteristic are usual. If there should indeed be operated in the worrking point R, it is necessary to load the air bearing with a force which is equal to W_R. In the present case, this load is obtained by means of a magnetic pre-tension $F_V = W_R$, which is also larger than the maximum occurring tensile force and pressure force, respectively, in the rod 21. The maximum load of the bearing is therefore equal to the sume of the magnetic pre-tension F_V and the maximum pressure force, while the minimum load ofthe bearing is equal to the pre-tension F_V minus the maximum tensile force. Preferably, the maximum load is chosen to be smaller than W_2 and the minimum load is chosen to be larger than W_1. In order to obtain a magnetic pre-tension corresponding to the point R, it is necessary that the cuve II (only the linear part of the curve II is shown) of the magnetic attraction force F has a point of intersection with the curve I of the bearing capacity W which coincides with the point T. Since in general the magnetic pretension F_V corresponds to a magnetic gap H_m located outside the region of air gaps $H_{a\ max}$ -$H_{a\ min}$(H_m > H_{a} max), a specific step has to be taken to cause the point of intersection of the curves I and II to coincide with the point R which is chosen to be the working point. This step consists in that a magnetic gap H_m is used which exceeds by an amount S the air gap H_a. As shown with the detail illustrated in Fig. 10, this is achieved either by arranging the magnets 33, 35, 37 at a distance S from the air gap in the supporting foot 27 or by providing the relevant surface of the carrier 5 with a layer 75 which magnetically behaves like air. The layer 75 then covers the magnetically conducting plate 49. In the present case, the magnets 33, 35 and 37 are arranged in the supporting feet 27, 29 and 31 at a distance S from the air gap. In the detail of the magnet arrangement illustrated in Fig. 10, this is indicated in dotted lines. The carrier 5 is supported on the table 1 in the vertical direction Z by means of a specific layer 87, as will be described more fully hereinafter. It should be noted that with arrangements by means of which very accurate displacements have to be performed, a comparatively large rigidity

$$\frac{dW}{dH_a}$$

of the air bearing in a comparatively large region of air gaps ($H_{a\ max}$ -$H_{a\ min}$) will be aimed at so that load variations will have a smallest possible influence on the size of the air gap and hence on the position of the object to be displaced.

As appears from Fig. 10, there is operated in a region of magnetic gaps in which there exists a linear relation between the magnetic attraction force F and the magnetic gap H_m. The part of the curve II utilized therefore is in fact a straight line. This is approximately the case when the air gap is sufficiently large and furthermore the value of the magnetic saturation of the magnet yokes 39, 41, 45 and 47 is comparatively high. However, it is preferable to choose for the magnet yokes 39, 41, 45 and 47 a material having a comparatively low magnetic saturation value (such as, for example, mild steel) so that the magnet yokes 39, 41, 45 and 47 become magnetically saturated in the region $H_{a\ max}$ -$H_{a\ min}$. The effect of the occurrence of magnetic saturation in the magnet yokes 39, 41, 45 and 47 will be explained with reference to the curve III in Fig. 10, which in this case has approximately the shape shown.

If it is assumed that the load of the bearing is subjected to a variation ΔW_a, the air gap H_a and also the magnetic gap H_m vary by an amount ΔH_a. The variation in the magnetic attraction force F corresponding to this amount ΔH_a is in the case of curve II ΔF_{II} and in the case of curve III ΔF_{III}. It will be clear that ΔF_{II} is larger than ΔF_{III} due to the flatter slope of curve III in the relevant region of air gaps. Due to the variation in magnetic attraction force F of a value ΔF_{II} and ΔF_{III}, respectively,in fact that the load W consequently also varies by an amount $\Delta W_{a\ m\ II}$ and $\Delta W_{a\ m\ III}$, respectively. Since $\Delta W_{a\ m\ II}$ is larger than $\Delta W_{a\ m\ III}$, in the case of curve II the limit value W_2 will consequently be reached earlier than in the case of curve III with load variations exceeding ΔW_a. This means that the region of the optimum bearing stiffness (W_2 -W_1) is consequently left earlier with magnet yokes 39, 41, 45 and 47 not becoming saturated than with magnet yokes becoming saturated. Preferably, a magnet configuration will therefore be chosen which yields a variation as shown for curve III. The ideal case arises if curve III on the lefthand side of the working point R approaches the line corresponding to the horizontal line through $F_V = W_R$. This line then forms an asymptote of curve III.

In the case of a rectangular carrier 5, the thrust bearings 7 can be arranged near the corners of the carrier, as shown diagrammatically in Fig. 1, or near the centres of the sides of the carrier, as shown in Figures 2, 6, 7, 8 and 11. The thrust bearings 7 for supporting the carrier 5 in the Z-direction are preferably arranged in the manner shown in Figures 2, 6, 7, 8 and 11 for the sake of constructional simplicity. Each of the four thrust bearings 7 is composed of an assembly of nine permanent samarium-cobalt magnets 77, which are separated from each other by eight magnet yokes 79 of magnetically good conducting material, such as mild steel. The assembly of nine magnets 77 is separated from a box-shaped holder 81 of poor magnetically conducting material, such as, for example, aluminium, by two magnet yokes 83 and 85 of mild steel. The magnets 77 and the magnet yokes 79, 83 and 85 are plate-shaped and rectangular. The direction of magnetization of the two assemblies of magnets 77 extending parallel to the X-direction is parallel to the X-direction, while the direction of magnetization of the two assemblies of magnets 77 extending parallel to the Y-direction is parallel to the Y-direction (Figures 7, 8 and 11). However, these directions of magnetization may alternatively be as indicated in Figure 2, i.e. rotated through 90° with respect to the aforementioned directions. The upper surface of the table 1 made of soft magnetic material, such as, for example, mild steel, is covered by replicated layer 87. This replicated layer 87 is made of an epoxy resin with a filler, such as, for example, aluminium oxide, which magnetically behaves like air (Fig. 6 and the illustrated detail of Fig. 10). By means of the replicated layer 87, the magnetic air gap is enlarged effectively by an amount S so that $H_m = H_a + S$. As already stated, it is thus achieved that the curve of the magnetic attraction force F, has its point of intersection with the curve of the bearing capacity W at the working point R. Furthermore, the replica layer 87 protects the carrier 5 of mild steel from corrosion. By means of a master plate, which is extremely flat, the replicated layer 87 can be flattened during curing. This means that the upper surface of the table 1 need not be extremely flat. The extreme flatness ultimately required is thus obtained in a simple and time-saving manner by means of one master plate for many carriers. Summarizing, this consequently means that the replicated layer 87 has a threefold function. Due to the fact that the table 1 is made of soft magnetic material having a low remanence, the risk of small shocks during the movement of the carrier 5 owing to regions having a remanent magnetism induced by the magnets 77 in the table surface is reduced to a minimum. The carrier 5 is provided with a circumferential air duct 89, which is connected to a source of compressed air (not shown). The air duct 89 has a large number of lateral ducts 91, which are uniformly distributed over the circumference of the carrier (Figures 6, 7 and 8) and which open into the air gap between the carrier 5 and the table 1. As a result, an air bearing is obtained over a large part of the circumference of the carrier 5. It should be noted that no lateral ducts 91 are present at the area of the magnets 77. The regions of the air bearing and the magnetic pre-stress are consequently separated from each other.

The air bearings 7 are magnetically pre-stressed with a force F_V which is considerably larger than the maximum load in the Z-direction of the bearing. Preferably, F_V is chosen so that the working point of the bearing is located again in the point R of Fig. 10. The magnetic pre-tension is consequently not required in this case for absorbing tensile forces. The construction of the carrier is chosen to be as light as possible, as a result of which the overall load in the Z-direction constituted by the weight of the carrier 5 and the object 9 is only a fraction of the magnetic pretension F_V. With a view to variations in the load of the bearings 9 the same consideration applies as already indicated with reference to Fig. 10 with regard to the variations in H_a and H_m. The criterion again is that with variations in the load the variations in H_a and $H_m$must be as small as possible. It should be noted that also in this case it is preferably that the magnet configuration is chosen so that magnetic saturation occurs. For this purpose, the material of the magnet yokes 79, 83 and 85 must have a comparatively low saturation value.

In the second embodiment of the displacement arrangement shown in Fig. 4, there are only two coordinate directions X and Y; the drive in the third coordinate direction Y' is omitted in this case. Furthermore, the rod 23 is connected rigidly to the supporting foot 29 at the point 93. However, the rod 21 is pivotally connected to the supporting feet 24 in the same manner as in the displacement arrangement shown in Figures 1, 2, 3 and 6. As a result, a small angular adjustment α can be obtained if an alignment of the carrier 5 with respect to the table 1 is necessary. A small displacement of the rod 23 in the Y-direction permits of obtaining such an angular adjustment α. This angular adjustment in fact is a pre-adjustment or calibration, which precedes the displacements which have to bring the object to the working point P. The supporting feet 27 and 29 are again provided with permanent magnets, magnet yokes and air supply ducts, while the carrier 5 is provided with magnetically conductive plates as described in the positioning device shown in Fig. 1. The positioning device shown in Figure 4 belongs to the category in which a rotation ϕ_z about a vertical Z-axis is not necessary for positioning the object.

The third embodiment of the positioning device shown in Fig. 5 again belongs to the category in which a rotation ϕ_z about a vertical Z-axis is possible. Also in this case, the rotation ϕ_z is obtained by means of the rods 23 and 25. The supporting foot 27 is of the same type as that of the first positioning device, while the supporting feet 29 and 31 as such as omitted. The rods 23 and 25 are now pivotally coupled to a beam-shaped guide 95, which is longer than the distance between the rods and which is made of magnetically conductive material, such as, for example, mild steel. The coupling between the rod 23 and the guide 95 is of the same type as the coupling between the rod 21 and the supporting foot 27, while the coupling between the rod 25 and the guide 95 only comprises a length of wire 55 so that the guide 95 can pivot with respect to the rods 23 and 25. The carrier 5 accommodates two assemblies of permanent magnets 77. The magnet configuration is of the same kind as already described with reference to the positioning device shown in Fig. 1. In order to obtain a magnetic gap H_m larger than the air gap H_a, the magnets 77 are arranged so that their end faces are located at a distance S from the air gap. Alternatively, the aforementioned replicated layer having a thickness S may be used. This layer is then applied to the side of the guide 95 facing the magnets. On the carrier 5 is disposed an object 9, such as, for example, a circular semiconductor substrate, while, for example, the centre P' has to coincide with the working point P. An advantage of the positioning device shown in Fig. 5 is the comparatively high rigidity against rotations of the carrier 5 about a vertical Z-axis. Furthermore, it is possible with this arrangement to perform comparatively large displacements parallel to the X-direction with a comparatively small mass of the carrier 5.

In all the positioning devices described above, drives 11, 13 and 15 are used which will be described hereinafter with reference to Fig. 12. The translatory drive shownin Fig. 12 comprises a direct current motor 97, which drives a shaft 109 through a flexible coupling 99 and a series of frictional wheels 101, 103, 105 and 107. The rods 21, 23 and 25 each have two coplanar, longitudinally extending flat surfaces 115 and 117, and by means of two pairs of freely rotatable pressure rollers 111 and 113 which are spaced apart by a certain distance (see also Fig. 2) the rods 21, 23 and 25 are pressed with the flat surfaces 115 and 117 against the relevant driving shaft 109. The pressure rollers 111 and 113 are inclined with respect to a vertical plane and are journalled in a block 119 which is acted upon by a pressure force 121 provided by a spring (not shown). The rolling friction between the shaft 109 and the flat surfaces 115 and 119 of the rods 21, 23 and 25 oridyces a translation of these rods in the X-, Y-and Y' directions respectively. The rods 21, 23 and 25 each carry a stripshaped measuring scale 123 which extends in the X-, Y- and Y' direction, respectively, and which has alternating regions of comparatively strong and comparatively weak reflectivity onto which a light beam 125 is projected by means of a mirror 127 and a lens 129. The reflected light beam is detected by a photodetector arranged in a measuring device 131 in a manner not shown. The measurement signal thus obtained is processed in an electrical servo loop and is then fed back to the electric motor 97. The optical measuring device roughly described above is of the usual kind and is therefore not described in detail. It should be noted that the measuring direction coincides with the X-, Y- and Y' direction, respectively, as a result of which so-called Abbe errors or tilting errors are avoided.

In all the positioning devices described above air of gas bearings are used for the vertically operating thrust bearings 7. However, alternatively a liquid may be used as a viscous medium in the thrust bearings 7. In that case it is necessary for the outflowing liquid to be collected in a satisfactory manner. Although essentially a liquid may be used as a viscous medium for the horizontally operating thrust-tensile bearings, preferably a gas is used because of the relatively complicated collecting means required for a liquid. The vertical thrust bearings may also be replaced by accurate roller-or ball-bearings, while sliding bearings are also possible. The pre-tension of the viscous contactless bearings can be obtained by means of a weight, a vacuum, a spring or electromagnetically for the vertically operating thrust bearings and by means of vacuum, a spring or electromagnetically for the horizontally operating thrust-tensile bearings. In the case of an electromagnetic pre-tension, the permanent magnets are replaced by an electromagnet whose excitation can be controlled by means of a sensor by which the size of the air gap is measured. The magnetic attraction force can then be controlled so that variations in the load of the air bearing or liquid bearing are fully compensated for by an adapted excitation. A variation of the magnetic attraction force F corresponding thereto is indicated in Fig. 10 by the dot-dash line IV. It should be noted that the usual electromagnetic bearings which do not use of a viscous medium originating from a pressure source do not fall within the scope of the invention. Such electromagnetic bearings are in fact of the dynamic type, whereas according to the invention viscous bearings of the static type with an external pressure source are used.

Instead of an assembly of permanent magnets, according to the invention a single permanent magnetmay be used for each rod 21, 23 and 25. Essentially, it is also possible to use a single magnet for the vertical support of the carrier. The required stiffness against tilting of the carrier 5 can be obtained more readily,however, by several magnets or, as described, by several assemblies of magnets. Although the invention has been described with reference to a translatory drive or a linear drive with friction couplings, other known linear drives may alternatively be used. Such linear drives may be, for example, screw-and nu drives or drives with a shaft guided by rollers or balls. Essentially, any drive can be used in which a reciprocating translatory movement in either of the reciprocal direction is imparted to the carrier 5 by the action of a force from one side of the carrier 5. The described static viscous bearings with an external pressure source may be of different types with regard to the restriction used between the pressure source and the gas and liquid gap, respectively. More particularly, the possibility of the use of a diaphragm-compensated viscous bearing is mentioned. With such a bearing, which is known <u>per se</u>, a very high degree of stiffness can be obtained.

Claims

1. A positioning device comprising a horizontal plate-shaped carrier which is slidably supported on a flat table and is displaceable in two orthogonal coordinate direction, which device is provided with a first translatory drive coupled to the carrier for exerting a pressure force on the carrier in a first coordinate direction and with a second translatory drive coupled to the carrier for exerting a pressure force on the carrier in a second coordinate direction at right angles to the first coordinate direction, the forces exerted on the carrier by the first and the second drive acting in one horizontal plane, characterized in that the first drive is coupled to the carrier in a contactless manner by means of a first horizontally operating static thrust and tensile bearing, respectively, via a viscous medium while the second drive is coupled to the carrier in a contactless manner by means of a second horizontally operating thrust and tensile bearing, respectively, via a viscous medium,both the first and the second thrust and tensile bearings, respectively, being pre-stressed in the first and second coordinate direction, respectively, with a force which is larger than the maximum tensile force occurring between the first and the second drive on the one hand and the carrier on the other hand.

2. A positioning device as claimed in Claim 1, characterized in that the device is provided with a third translatory drive coupled to the carrier for exerting a pressure force and a tensile force, respectively, on the carrier in a direction parallel to the second coordinate direction, the first, the second and the third drive each being pivotable about a vertical axis with respect to the carrier.

3. A positioning device as claimed in Claim 2, characterized in that the third drive is coupled to the carrier by means of a third horizontally operating static thrust and tensile bearing, respectively, via a viscous medium, the third bearing being pre-stressed parallel to the second coordinate direction with a force which is larger than the maximum tensile force occurring between the third drive and the carrier.

4. A positioning device as claimed in Claim 3, characterized in that the first, the second and the third bearing are pre-stressed by means of a permanent magnet arranged therein.

5. A positioning device as claimed in Claim 4, characterized in that a part of the magnetic circuit corresponding to the permanent magnet is in the state of magnetic saturation.

6. A positioning device as claimed in Claim 4, characterized in that the viscous medium is air.

7. A positioning device as claimed in Claim 4, characterized in that the second and the third bearing are pre-stressed by means of a number of permanent magnets common to both bearings, which are arranged in the carrier.

8. A positioning device as claimed in Claim 7, characterized in that the second and the third bearing are coupled to each other by means of a beam-shaped guide, which is pivotable with respect to the second and the third drive about a vertical axis, while the first drive is pivotable about a vertical axis with respect to the carrier.

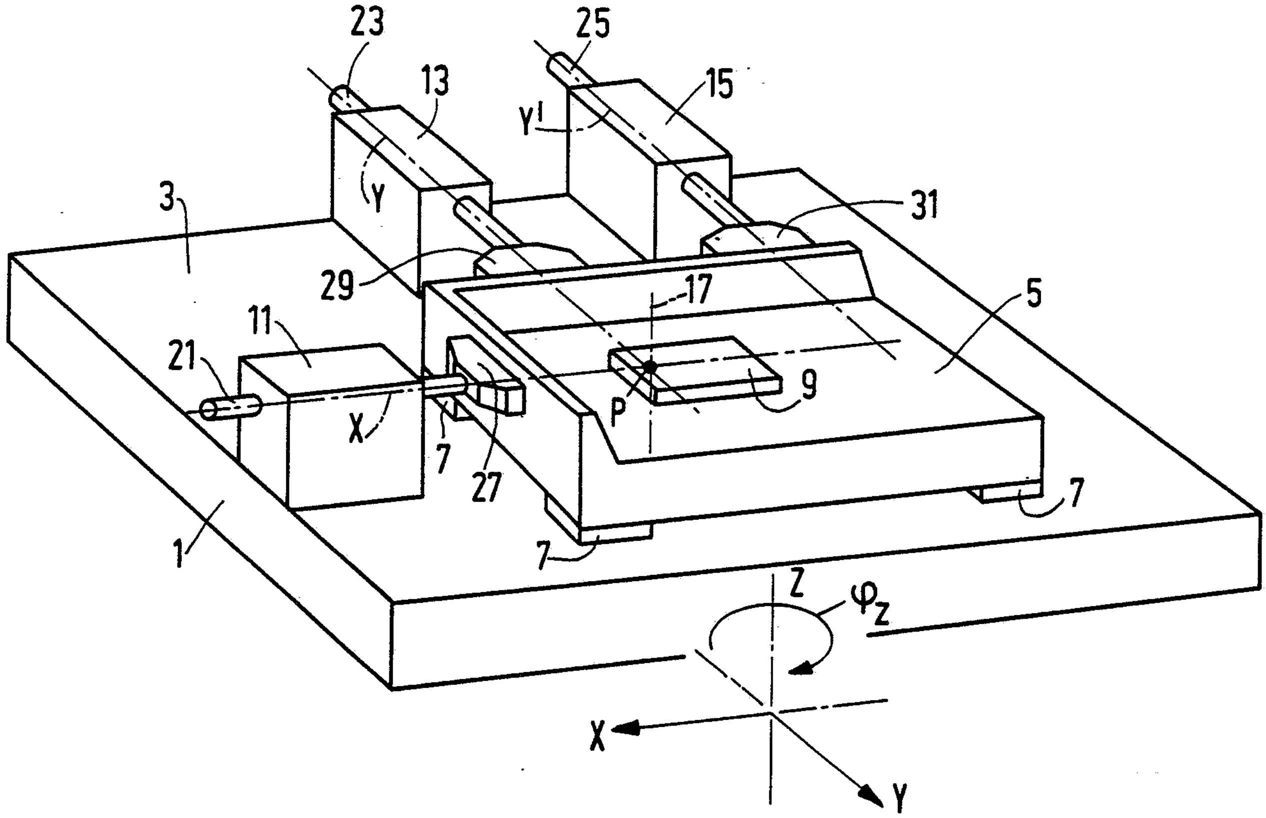
23
25
13
15
Y'
Y
3
31
29
17
5
11
21
9
P
X
7
27
7
7
1
Z
φz
X
Y

FIG.1

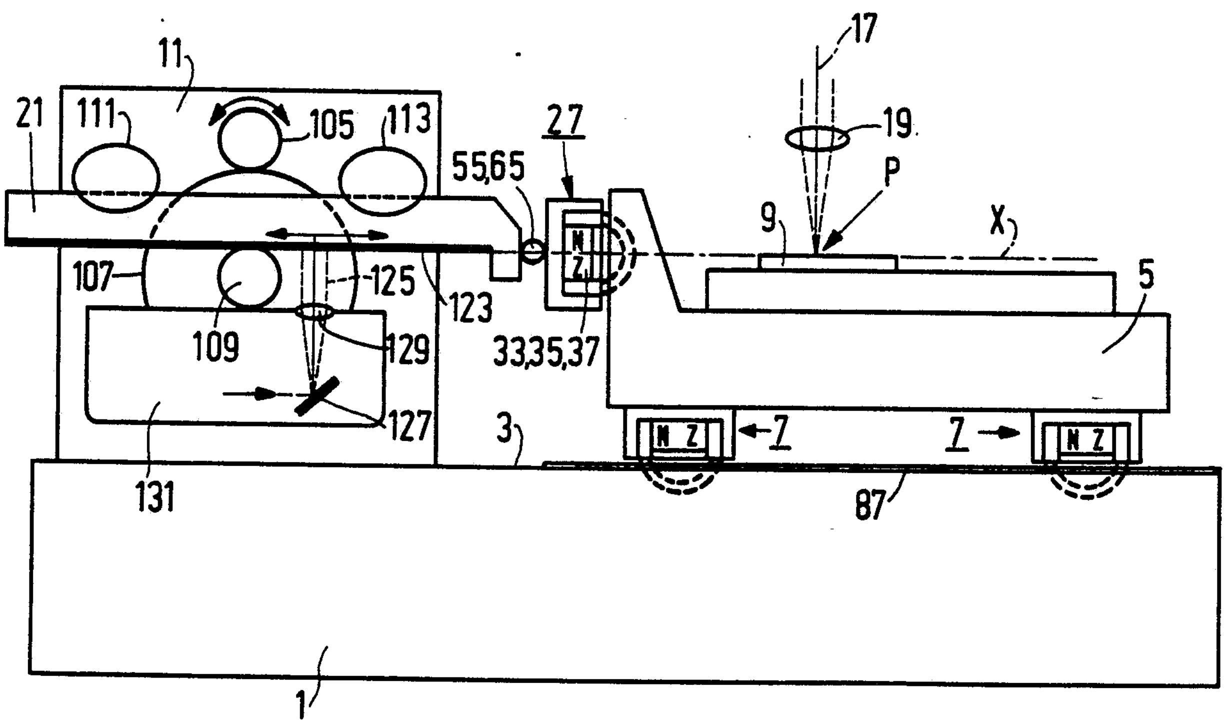
11
21
111
105
113
27
17
19
55,65
P
9
X
5
107
125
123
109
129
33,35,37
127
131
3
N Z
7
7
N Z
87
1

FIG.2

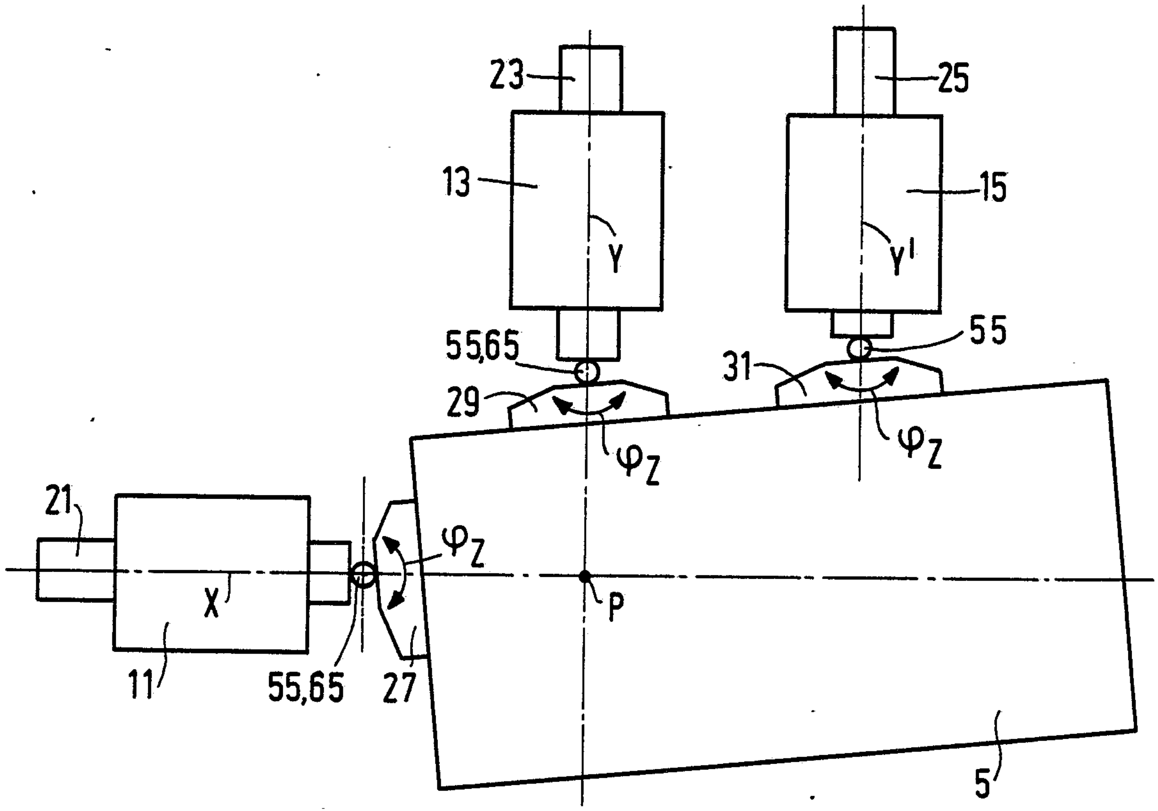
23
25
13
15
Y
Y'
55,65
55
31
29
φZ
φZ
21
φZ
X
P
11
55,65
27
5

FIG.3

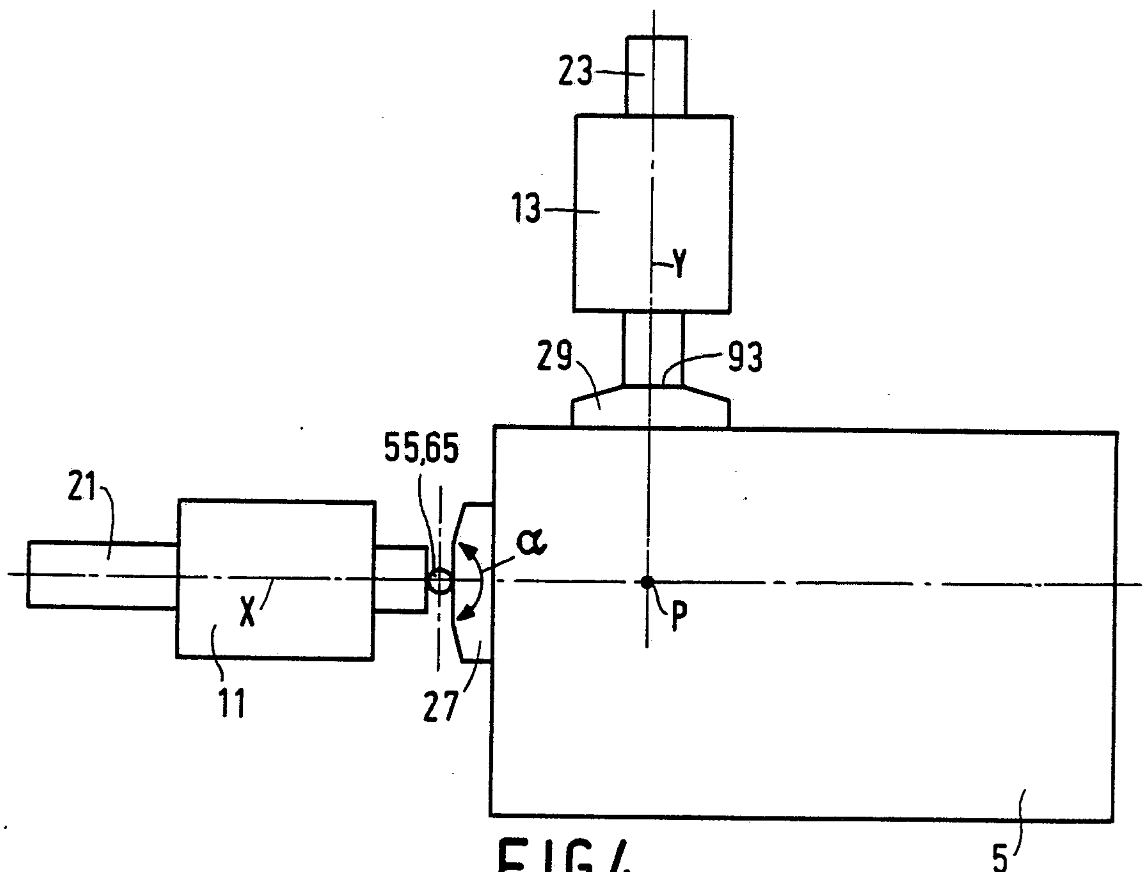
23
13
Y
29
93
55,65
21
α
X
P
11
27
5

FIG.4

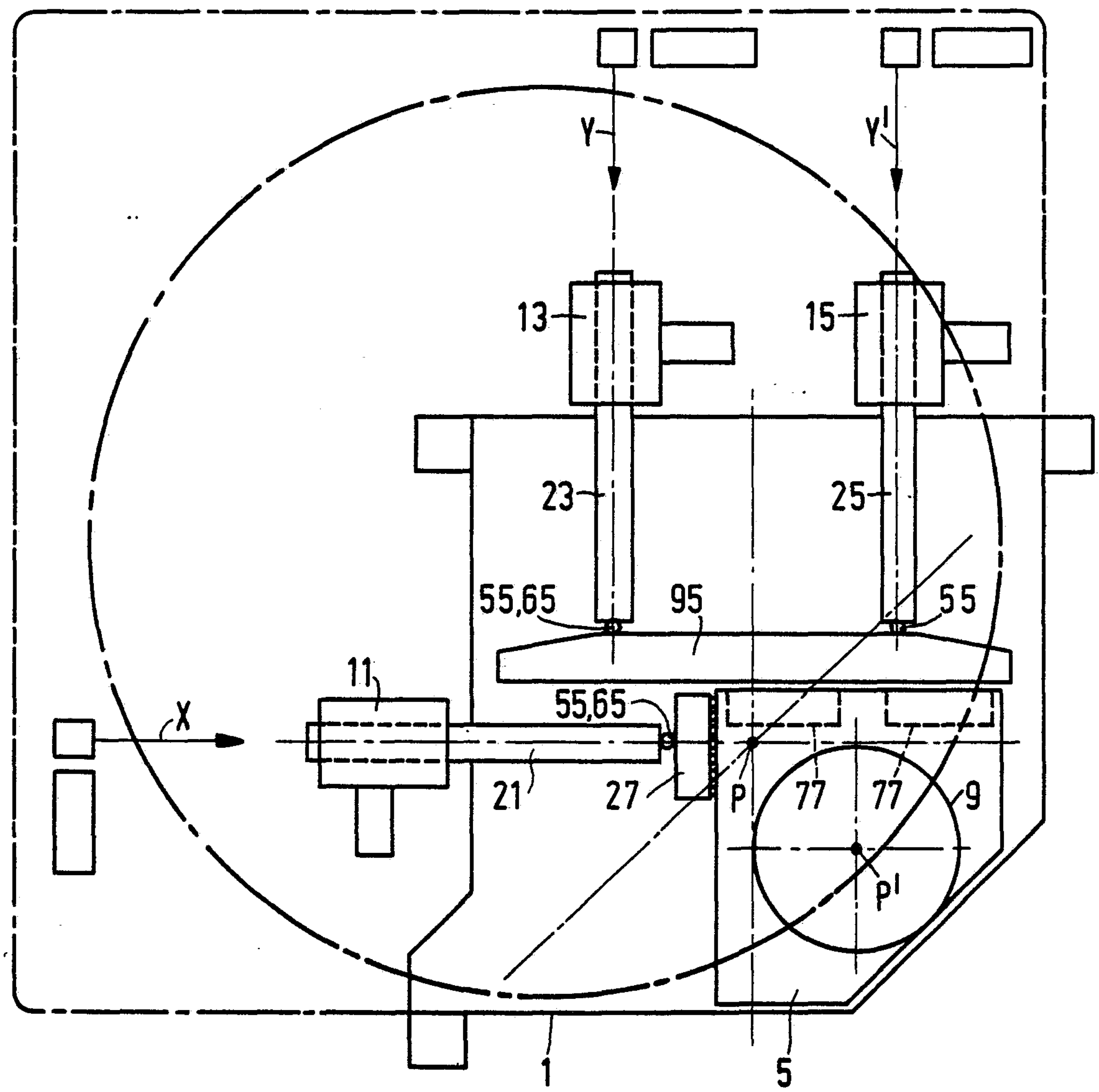

FIG.5

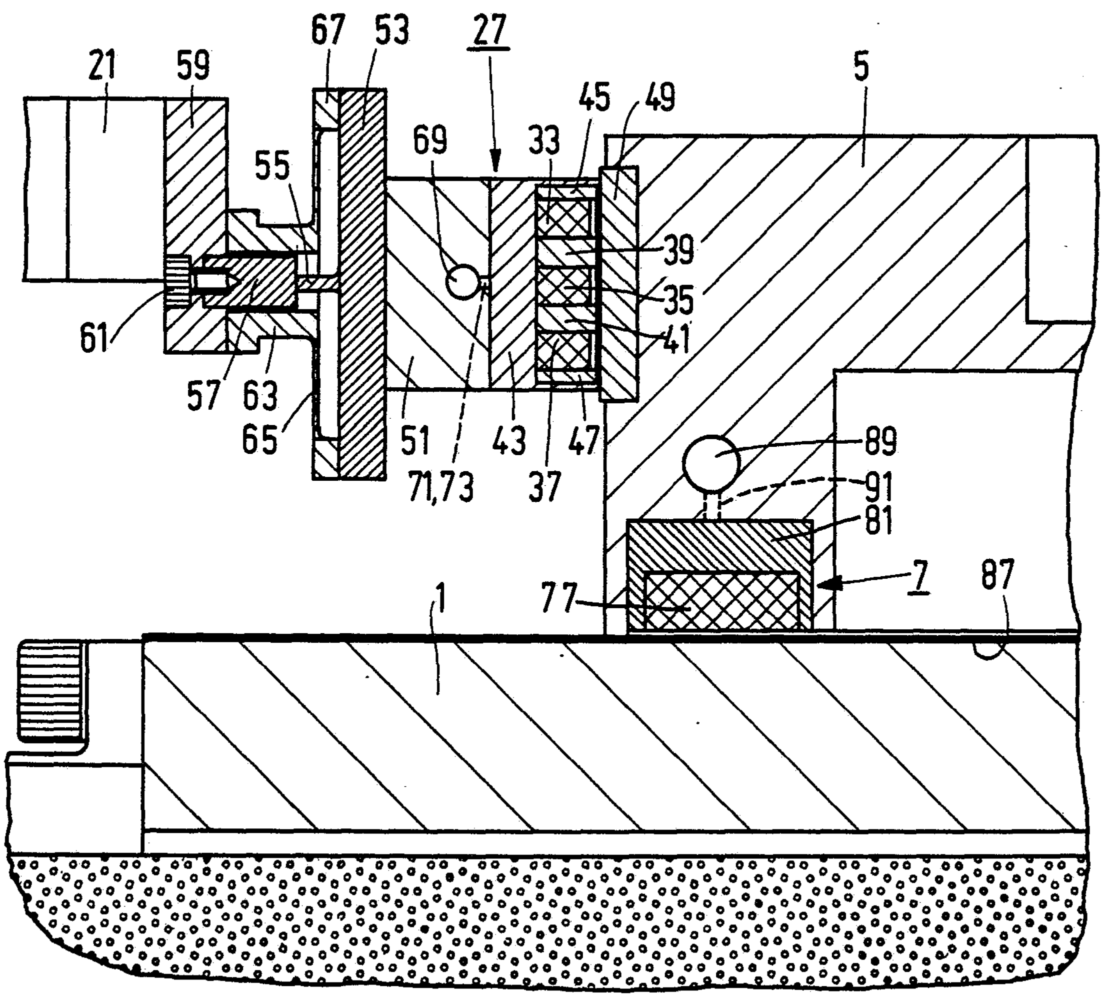
67
53
27
21
59
5
45
49
69
33
55
39
35
61
41
57
63
65
51
43
47
89
71,73
37
91
81
7
87
1
77

FIG.6

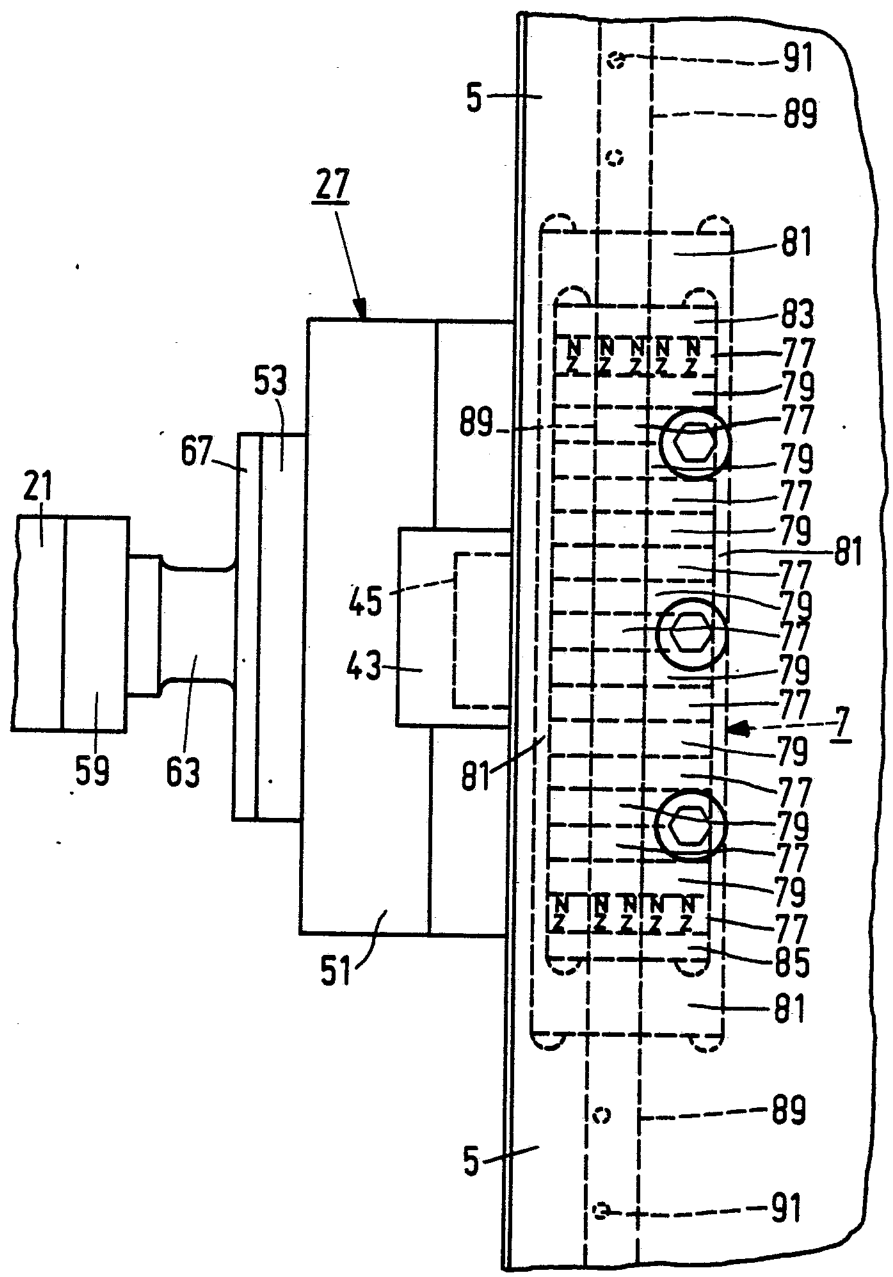
5
27
91
89
81
83
77
79
89
77
79
77
79
81
77
79
77
79
77
7
79
77
79
77
79
77
85
81
53
67
21
45
43
59
63
81
51
89
5
91
N
Z

FIG.7

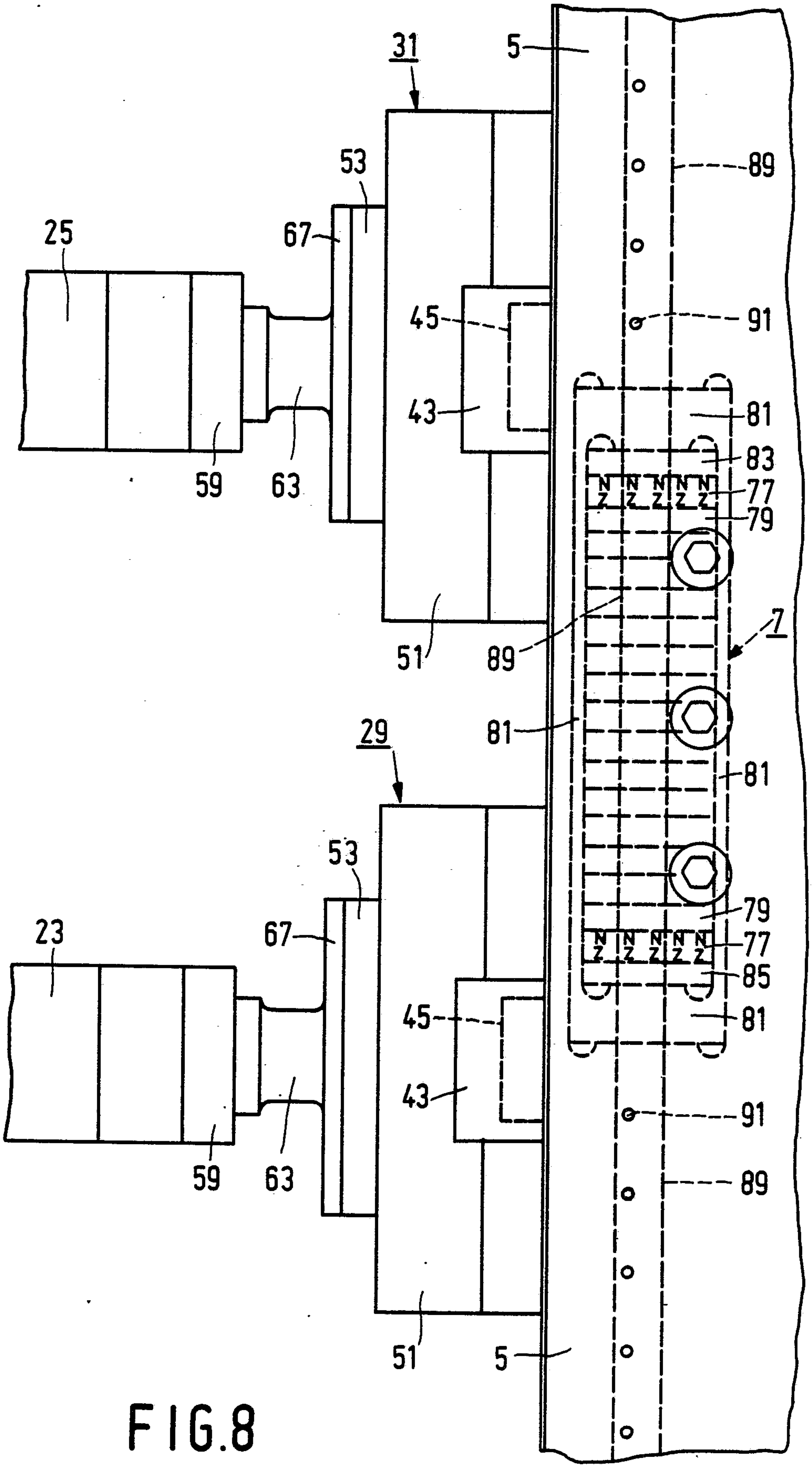
31
5
53
89
25
67
45
91
43
81
83
59
63
N Z
77
79
51
89
7
29
81
81
53
23
67
79
77
85
45
81
43
91
59
63
89
51
5

FIG.8

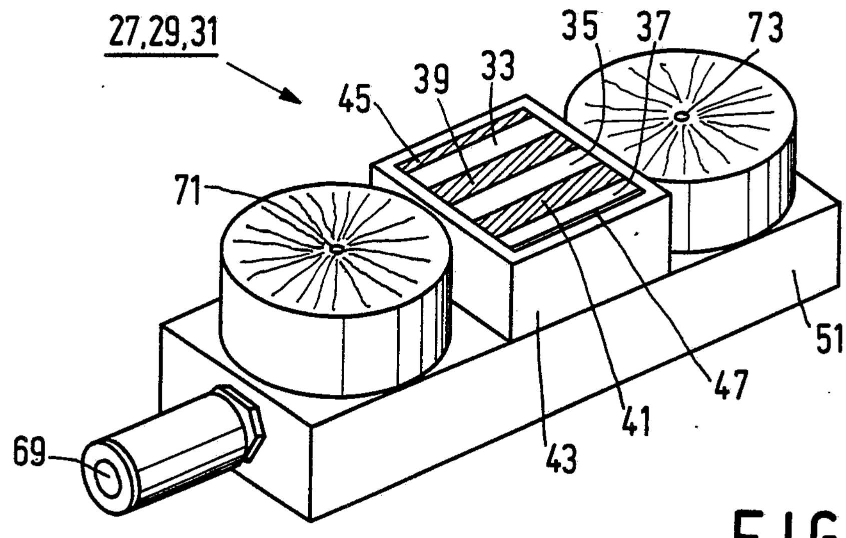
27,29,31
35
37
73
45
39
33
71
51
47
41
43
69

FIG.9

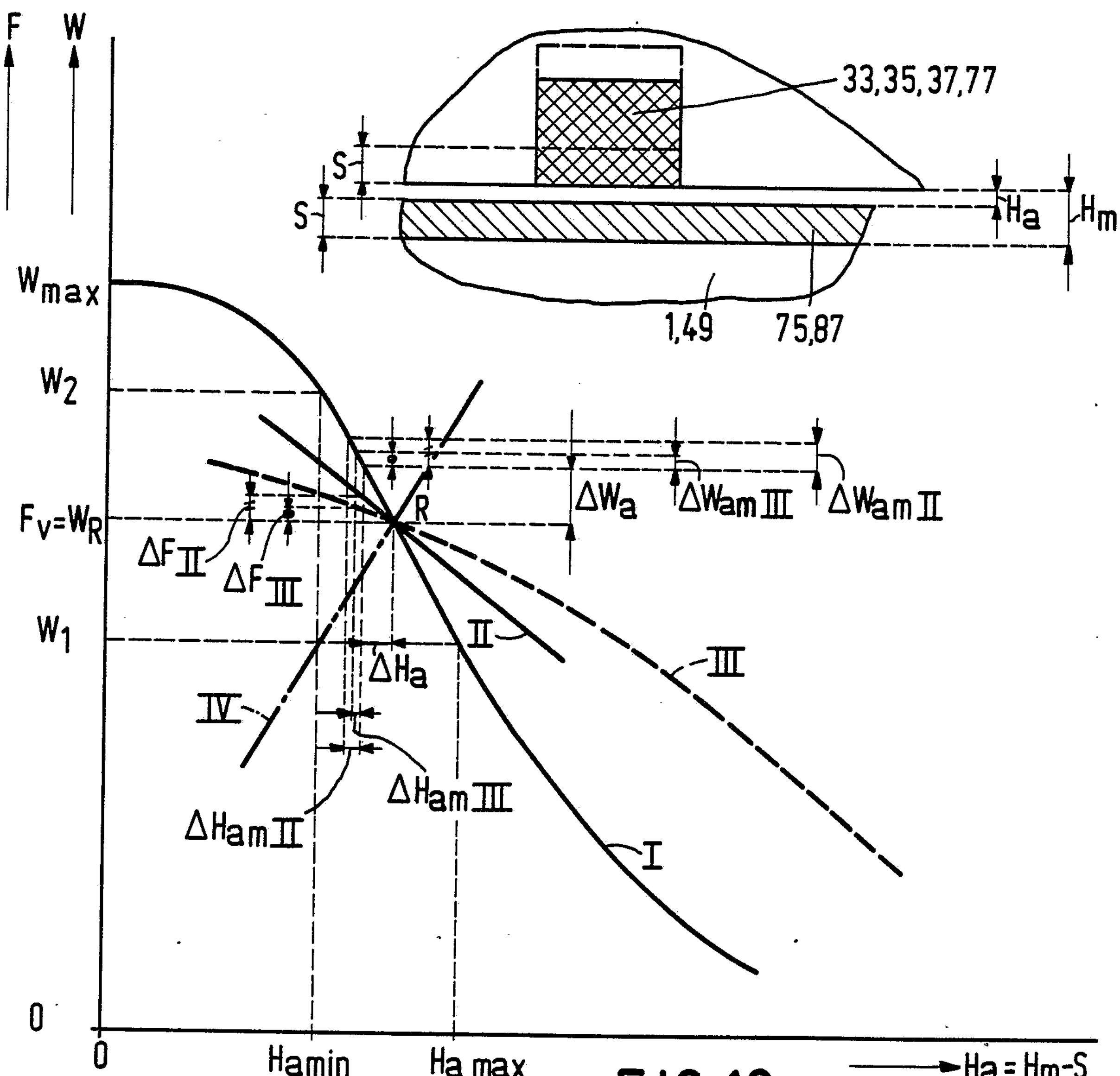
F
W
33,35,37,77
S
S
Ha
Hm
1,49
75,87
Wmax
W2
ΔWa
ΔWam III
ΔWam II
R
Fv=WR
ΔF II
ΔF III
W1
ΔHa
II
III
IV
ΔHam III
ΔHam II
I
0
0
Hamin
Ha max
Ha = Hm-S

FIG.10

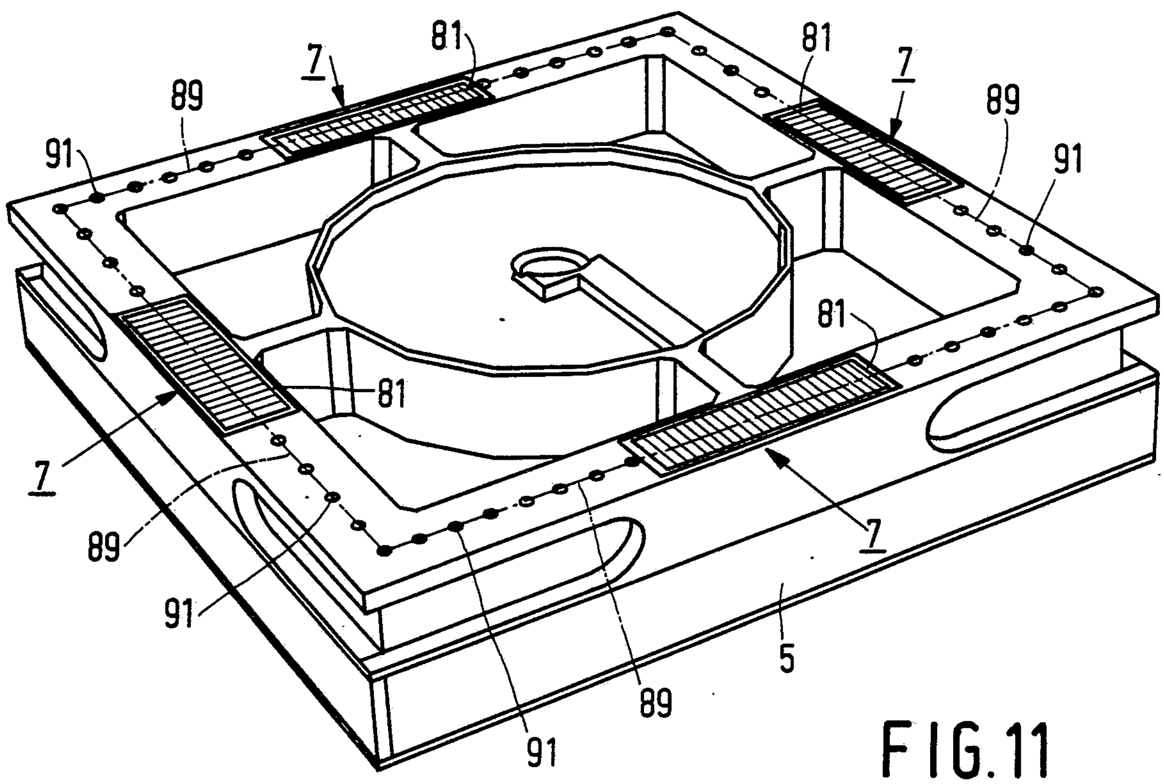
81
7
89
91
81
7
89
91
81
81
7
89
91
7
89
91
5

FIG.11

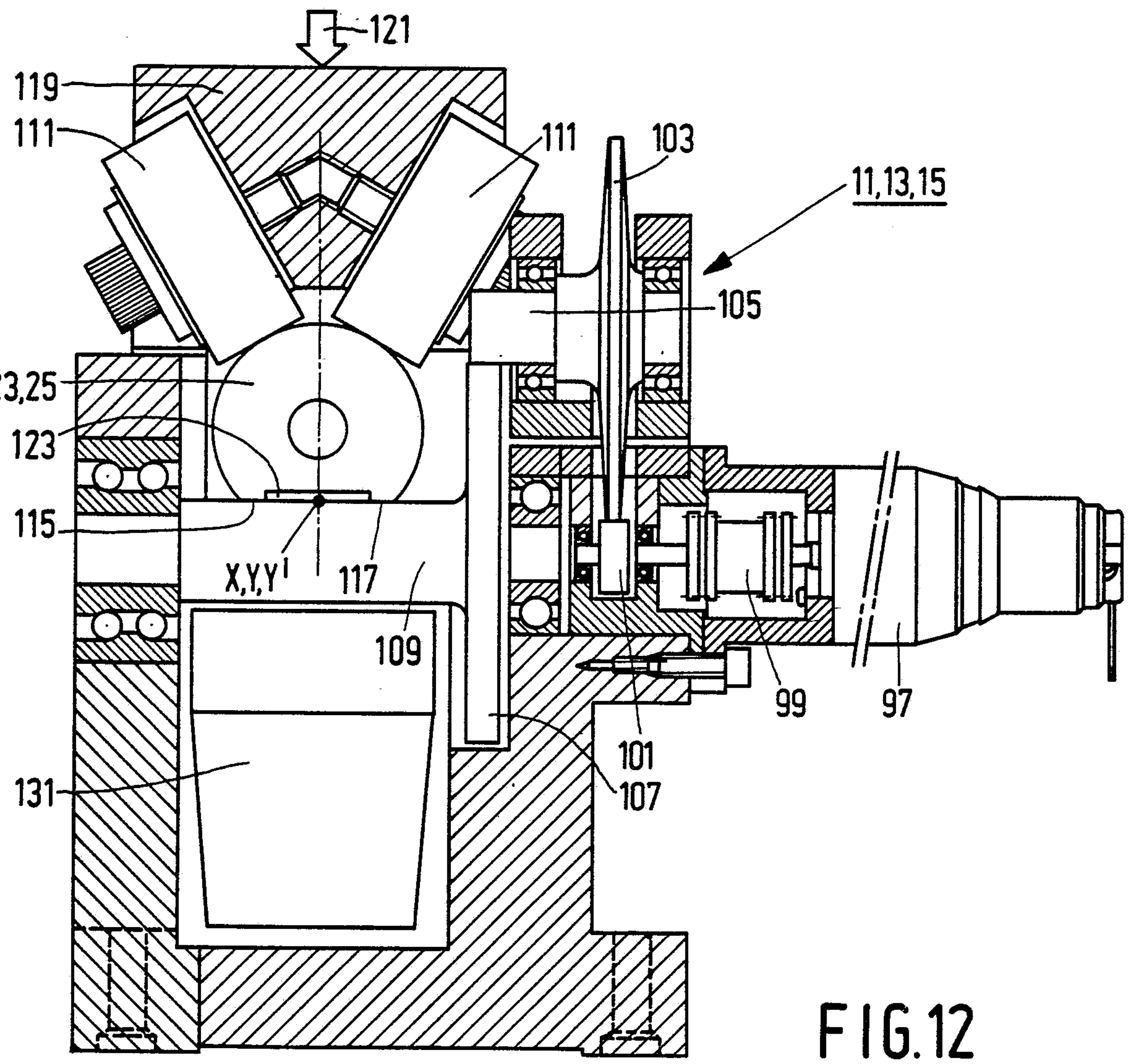
121
119
111
111
103
11,13,15
105
21,23,25
123
115
X,Y,Y'
117
109
99
97
101
131
107

FIG.12

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 86 20 0456

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	DE-A-1 497 263 (TELEFUNKEN) * Page 4, lines 19-30 *	1	B 23 Q 1/18 B 23 Q 1/26 F 16 C 32/06 G 01 B 5/00 H 05 K 13/00
Y	US-A-3 272 568 (KOORNEEF) * Claim 1 *	1	
A	FR-A-2 397 266 (DEA)		
A	DE-A-2 440 088 (CITIZEN)		
A	NL-A-7 213 848 (SPODIG)		**TECHNICAL FIELDS SEARCHED (Int. Cl.4)**
A	FR-A-1 193 636 (FOUQUET)		B 23 Q F 16 C G 01 B H 05 K
A	SU-A- 971 606 (BOBRIK)		
A	JP-A-58 109 238 (MITSUTOYO)		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	26-06-1986	DE GUSSEM J.L.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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